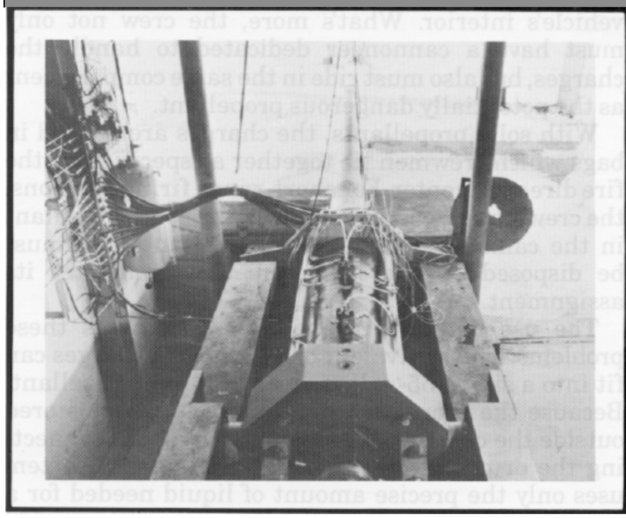
Liquid Propellants— A Potential Power Punch



by Mr. Bob Lessels

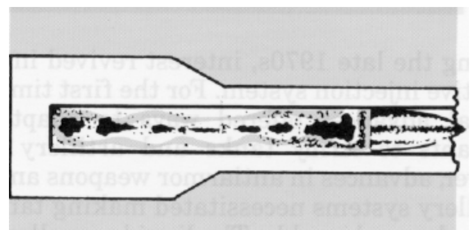
The Army's Ballistic Research Laboratory (BRL) is conducting research into liquid propellants for Army tank and artillery ammunition. Program managers believe that their efforts may lead to a revolution in armored vehicle design, ammunition handling, logistics, and combat crew safety—not to mention billions of dollars in savings.

Army studies on liquid propellants began in the late 1940s when researchers looked at two systems using liquid propellants. The first system, commonly termed bulk-loaded, simply involved injecting a specified amount of propellant into a gun chamber and igniting it. This system proved to be impractical in weapons where repeatability is important. Chamber pressures and muzzle velocities of the projectiles varied significantly due to hydrodynamic instabilities in bulk-loaded systems. Today, experts see little potential for this form of liquid propellant guns, except perhaps as air defense cannons or small caliber weapons.

The second system, known as regenerative injection, is much more promising. It involves using a piston to force the liquid propellant in the form of a jet or spray into the gun chamber during the combustion process. The result is a controlled burn. With this system, the liquid propellant can be metered accurately, and repeatable pressures and muzzle velocities can be achieved.

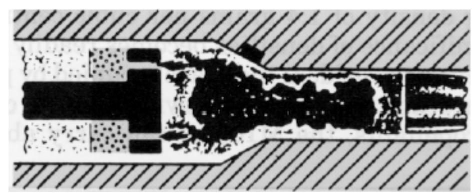
Exploration of both systems accelerated as a result of the Korean War, and by the mid-1950s the Army was exploring the design of a tank gun based on a liquid propellant concept. However, 1950s technology proved lacking and the program languished.

EVOLUTION OF PROPULSION CONCEPTS



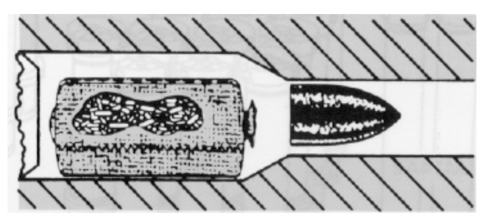
LP BULK LOADED

- SIMPLE
  BUT
- DIFFICULT TO CONTROL



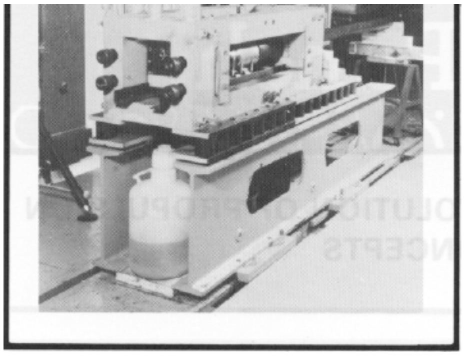
REGENERATIVE INJECTION

- BALLISTIC CONTROL
  BUT
- MECHANICALLY COMPLEX



SOLID PROPELLANT

- UNDERSTOOD
  BUT
- MATURE



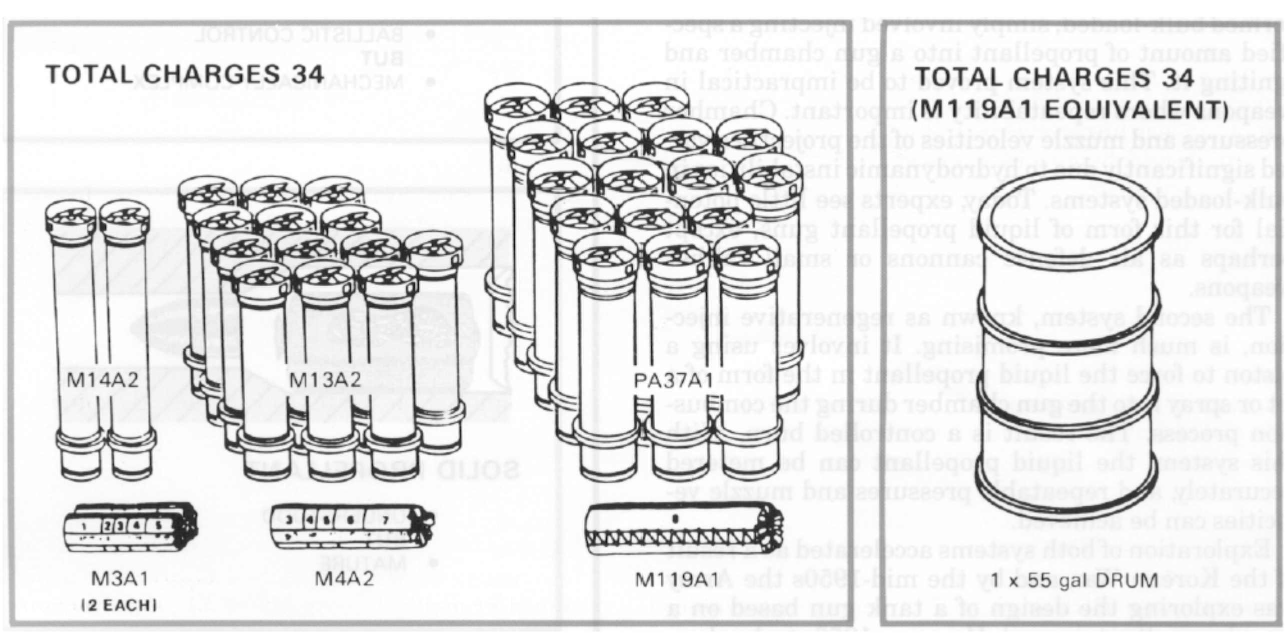
During the late 1970s, interest revived in the regenerative injection system. For the first time, technological advances offered ways to adapt liquid propellants to Army tanks and artillery pieces. Moreover, advances in antiarmor weapons and counterartillery systems necessitated making tanks and artillery less vulnerable. The liquid propellant gun's time had evidently arrived. In fact, the new technology promises to deliver tanks and artillery systems that are smaller, faster, and less vulnerable to enemy threats.

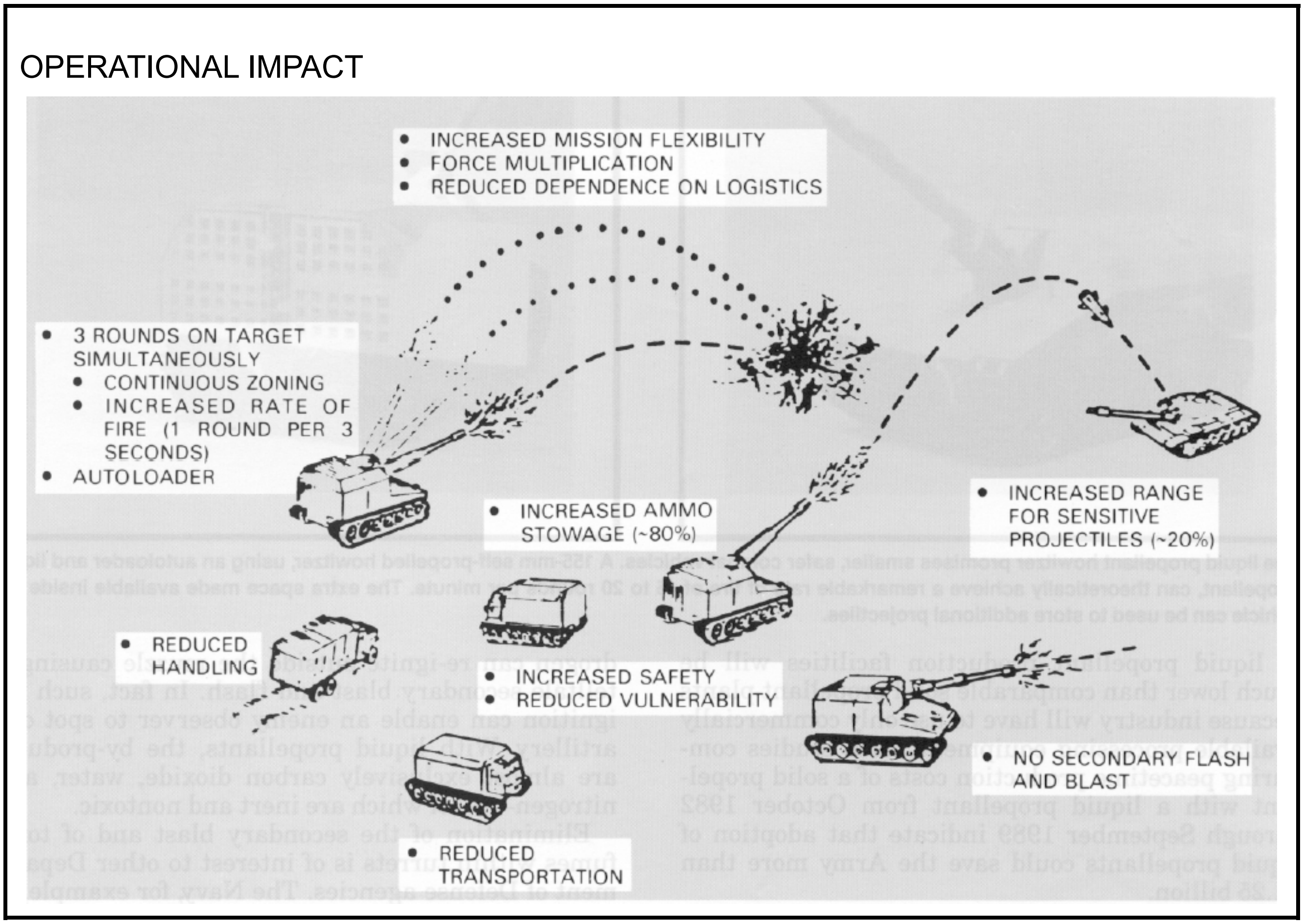
Because liquid propellants have a high density, they pack more energy into a smaller volume. Typically, solid propellants have a 1 gram per cubic centimeter packing density, but liquid propellants have a packing density of 1.4 grams per cubic centimeter. The significance of densities becomes readily apparent when one considers the space occupied by propelling charges in the M109A2 howitzer. Using current solid propellants, the M109A2 can carry about 34 propellant charges for its projectiles. Each charge is in an individual canister which can weigh as much as the propellant itself. The 32 canisters (the M3A1 charge is packed two per canister) occupy much of the vehicle's interior. What's more, the crew not only must have a cannoneer dedicated to handle the charges, but also must ride in the same compartment as the potentially dangerous propellant.

With solid propellants, the charges are packed in bags which crewmen tie together as specified by the fire direction center. For short-range firing missions, the crewmen discard a portion of the solid propellant in the canister. This wasted propellant then must be disposed of after the gun crew completes its assignment.

The use of liquid propellants eliminates these problems. The equivalent of 34 M119A1 charges can fit into a single 55-gallon drum of liquid propellant. Because the propellant is a liquid, it can be stored outside the crew compartment, with a hose connecting the drum to the artillery piece. Such a system uses only the precise amount of liquid needed for a particular range, thereby eliminating the waste found with solid propellants. And, because the liquid passes directly into the gun chamber automatically, the need for an extra crewman to handle the propellant disappears. Although readily ignitable at gun chamber operating pressures, liquid propellants are difficult to ignite at ambient pressures. Their use in combat vehicle munitions should minimize vehicle loss which may occur as the result of projectile and spall impact on stowed solid propellants.

M109A2 BASIC LOADS SOLID vs LIQUID





An additional benefit associated with liquid propellants involves transportation of the chemicals. Federal and state laws strictly govern the transportation of solid propellants. Many bridges and tunnels cannot be used, and transportation routes must avoid highly populated areas. Such restrictions may not apply to less hazardous liquid propellants. This situation should bring down associated transportation costs.

In fact, because the components of the liquid propellants are not propellants by themselves, they can be transported much more freely and with far greater safety. Once the chemicals arrive at their storage depot, they can be kept in complete safety for an indefinite period.

Like transportation safety, vehicle vulnerability on the battlefield is also a major concern. Studies of vehicles destroyed in the 1973 fighting in the Middle East suggest that most vehicle losses resulted when the impact of antiarmor munitions triggered a secondary explosion of the ammunition carried in the vehicle. If the vulnerability of on-board ammunition is eliminated, BRL analysts feel many more armored vehicles hit by enemy weapons can be repaired and returned to action.

More significantly, liquid propellants promise to *save* the *lives* of crewmen. Experience suggests that if the on-board ammunition explodes, few vehicle occupants usually survive. If an antiarmor round should penetrate a vehicle carrying liquid propellants, only those soldiers caught in the small spall cone of fragments from the antiarmor weapon would be injured.

What this means for the Army of the future is smaller, safer combat vehicles. The propellant will require *less* storage space and *fewer* crewmen to handle it. The vehicles could not only be lighter because armor can be concentrated to protect the crew, but also faster because the lighter weight of the vehicle can be propelled with less demand on the engine's available horsepower.

Yet another advantage of the liquid propellant system is its potential cost savings. The system can be retrofitted to existing combat vehicles thereby reducing production costs. But even more significantly, the costs of the propellant will please most taxpayers. A standard packaged artillery charge costs about $60 per pound of propellant. An equivalent amount of liquid propellant costs about $1. Furthermore, the raw materials used in the production of liquid propellants are available commercially. Therefore, the cost

The liquid propellant howitzer promises smaller, safer combat vehicles. A 155-mm self-propelled howitzer, using an autoloader and liquid propellant, can theoretically achieve a remarkable rate of fire of 15 to 20 rounds per minute. The extra space made available inside the vehicle can be used to store additional projectiles.

of liquid propellant production facilities will be much lower than comparable solid propellant plants because industry will have to use only commercially available processing equipment. BRL studies comparing peacetime production costs of a solid propellant with a liquid propellant from October 1982 through September 1989 indicate that adoption of liquid propellants could save the Army more than $1.25 billion.

In wartime if ammunition demands reach levels projected by the Army, the potential savings would be enormous. Basing their study on 155-mm ammunition alone, the researchers projected monthly savings of about $200 million.

Of course, the real test of new weapons technology is its effectiveness on the battlefield. A 155-mm self-propelled howitzer, using an autoloader and liquid propellant, can theoretically achieve a remarkable rate of fire of 15 to 20 rounds per minute. Adjusting fire onto a target would be easier using liquid propellants because the amount of propellant used to launch the projectile can be metered more accurately than when using solid propellants. In fact, the "right" propelling charge is always there. Also, the extra space made available inside the vehicle can be used to store additional projectiles. The cannon can put *more* firepower on target *faster,* and it will be able to carry more projectiles which will reduce logistic support requirements.

Another concern for artillery crews deals with blast pressures near the cannon. Liquid propellants reduce the blast over-pressures caused by re-ignition of muzzle gases. Contemporary solid propellants produce carbon monoxide, hydrogen, carbon dioxide, water, and nitrogen oxides at the muzzle. Several of these gases are toxic, and carbon monoxide and hydrogen can re-ignite outside the muzzle causing a telltale secondary blast and flash. In fact, such re-ignition can enable an enemy observer to spot our artillery. With liquid propellants, the by-products are almost exclusively carbon dioxide, water, and nitrogen—all of which are inert and nontoxic.

Elimination of the secondary blast and of toxic fumes within turrets is of interest to other Department of Defense agencies. The Navy, for example, is investigating the use of liquid propellant gun systems on its warships. They too realize the technology offers greater safety to gun crews as well as reduced danger to crewmen outside the weapon's turret. What's more, liquid propellants also reduce the need to protect ammunition storage areas with heavy armor.

Implementation of the liquid propellant technology is still 4 to 5 years in the future. Experts have proven the concept using 30-mm cannons. In fact, General Electric Company has independently demonstrated a rate of fire of about 500 rounds per minute in such a weapon. BRL researchers are now working not only to scale this technology to 155-mm caliber but also to establish the shelf life of the propellant. Even the disposal or demilitarization of the liquid propellant offers an unusual advantage. The simplest and most beneficial way of getting rid of waste stocks of a propellant may be to dilute it with water and pour it onto any farm field. BRL chemists report that the propellant is an excellent fertilizer!

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